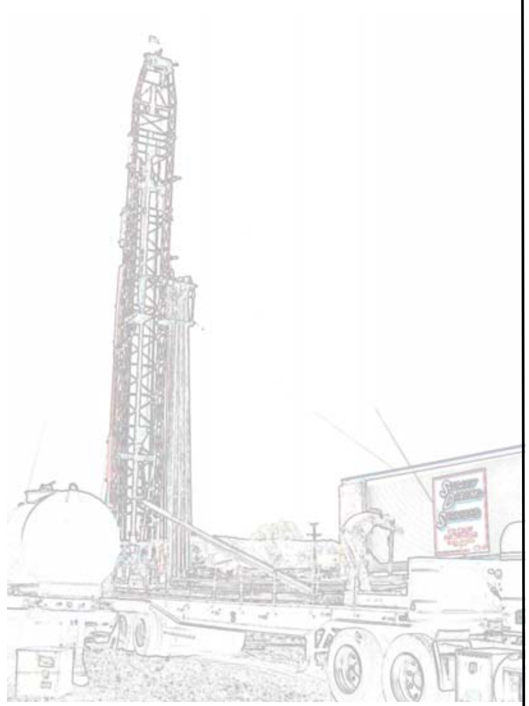
I'SOT GEOTHERMAL DISTRICT HEATING DEMONSTRATION PROJECT GEO-99-005



FINAL REPORT

Prepared For:
California Energy Commission

Prepared By:
I'SOT Incorporated

MARCH 29, 2004
CEC-500-2004-904
ISOTGEO-002

Prepared By:
I'SOT Incorporated
Dale Merrick
Canby, California
Contract No. GEO-99-005

Prepared For:

California Energy Commission

Karen Chase
Grant Agreement Manager

Jesselyn Rosales
Project Manager

Elaine Sison-Lebrilla
Program Manger
Research and Development Office

Robert L. Therkelsen
Executive Director

Table of Contents

List of Tables

List of Figures

Appendix

Acknowledgments

I'SOT Incorporated and project partner Modoc Contracting would like to thank the following for funding, support and assistance on the I'SOT Geothermal District Heating Demonstration Project:

Governor Arnold Schwarzenegger
Former Governor Grey Davis
State Senator Rico Oller

California Energy Commission:

William J. Keese
Arthur H. Rosenfeld
James D. Boyd
John L. Geesman
Robert Pernell

California Energy Commission Staff:

Elaine Sison-Lebrilla, Manager, Geothermal Program
Karen Chase
Roger Peake
Jesselyn Rosales
Karen Shimada
Gail Wiggett

Rohy Consulting:

Dr. David Rohy

OIT Geo-Heat Center:

John Lund
Kevin Rafferty
Gene Culver

Department of Energy, Idaho Operations Office:

Willettia Amos
Jay Nathwani

National Renewable Energy Laboratory:

Gerry Nix

Russell Hewett

Central Valley Regional Water Quality Control Board:

James C. Pedri
James Rohrbach

Plumas Geo-Hydrology:

Burkhard Bohm

U.S. Fish and Wildlife Service:

Tony Hawks
Stewart Reid

Modoc County Planning Department:

Scott Kessler
Dave Alvord

MHA Environmental Consulting:

Laurie McClenahan-Hietter

California Department of Oil, Gas and Geothermal Resources:

Liz Johnson
Linda Campion

1. Background

The I'SOT Geothermal District Heating Demonstration Project (I'SOT Project) is located in Modoc County, California in the town of Canby. Modoc County has extensive low temperature geothermal resources as evidenced by nearby hot springs and warm domestic wells.

High energy costs and a warm domestic water well prompted I'SOT Inc., a non-profit 501(c)(3) organization, to request assistance from the Oregon Institute of Technology (OIT) Geo-Heat Center to investigate the geothermal potential in Canby. After positive results from an initial Geo-Heat Center review, I'SOT Inc. answered a solicitation from the U.S. Department of Energy, Idaho Operations Office, to drill a 1600-foot exploratory geothermal well on I'SOT property. In November 1998, the DOE approved funding contingent upon obtaining a materials only grant from the California Energy Commission (Energy Commission) for a district heating system. In June 1999, the Energy Commission granted funding to I'SOT Inc. project partner Modoc Contracting, to construct a geothermal district heating system contingent on a usable geothermal resource resulting from the DOE assisted drilling. A California Environmental Quality Act (CEQA) review with a Mitigated Negative Declaration in 2001 and obtaining an NPDES discharge permit in 2002 set the stage for project construction for I'SOT Inc.

In February 2001, I'SOT Inc. answered a Phase I solicitation from the National Renewable Energy Laboratory (NREL), a DOE laboratory, to provide engineering and permitting for the I'SOT Project. A meeting in September 2002 brought the Energy Commission and NREL together as participants. A National Environmental Protection Act (NEPA) study was also started in September 2002, to allow Federal participation, and was finished on March 10, 2003 to allow NREL participation in Phase II construction. After NREL environmental requirements were satisfied, Native American issues were resolved and the weather permitted, project construction began in earnest in May 2003.

The I'SOT Project is a case study in geothermal direct-use morphology. It took the flexibility and perseverance of I'SOT Inc., as well as all funding agencies involved, to successfully modify the original plan to effectively reach project objectives. The following items dramatically affected the initial project design and timetable:

- Longer than expected length of drilling program
- Diminished expected resource flow
- Higher resource temperature
- Challenging water chemistry
- Duration of environmental reviews

Because of other funding opportunities from NREL and the Idaho Operations Office, I'SOT Inc. was able to:

- Provide the engineering necessary to utilize a nominal geothermal resource to meet system requirements.

- Verify the effectiveness of activated carbon filters in laboratory testing to provide regulator approvals and demonstrate that surface disposal of geothermal effluent to surface waters is a viable option.
- Provide no risk to Energy Commission managed GRDA funding by assisting I'SOT Inc. in drilling an exploratory geothermal well, because the I'SOT proposal only asked for materials only funding upon successful drilling.

Today, the I'SOT Project stands as an example of what a state and federal partnership can do to utilize a low temperature geothermal resource. The I'SOT Project demonstrates that a relatively modest geothermal resource can provide effective space heating for marginally energy efficient buildings. Despite lower-than-expected resource flow and water quality problems concerning mercury and arsenic, I'SOT Inc. was able to work within the original materials-only Energy Commission budget and produce what could be a model for future small direct-use projects.

The following table indicates contributions of the funding participants in the I'SOT Project.

Table 1a

California Energy Commission	$	304,525.00
DOE, Idaho Operations Office	$	203,968.00
National Renewable Energy Laboratory	$	306,916.00
I'SOT Inc.	$	298,000.00
Donations	$	72,000.00
Project Total	$	1,185,409.00

This report is to satisfy Subtask 6.2.3 of the Energy Commission funding agreement for a project final report.

2. Project Objectives

Originally, project technical and economic performance objectives were to:

- Drill a 1600 ft. geothermal well that was capable of producing 200 gpm at 150-160°F.
- Construct a geothermal district heating system that would service 35 buildings (44,000 ft^2) in a residential area with space heat and domestic hot water.
- Construct a warm water wetland for the discharge of geothermal fluid.
- Reduce energy costs by 45% for the first three years of operation and 91% for each year thereafter.

The original plan also included an 8x8 central plant that would house the production pump and main heat exchanger. The retrofit plan incorporated heat exchangers at each building and would use existing hot water heaters for storage.

To achieve these objectives, I'SOT Inc. began a drilling program in April 2000 with a 75%-25% ($144,000 DOE, $48,000 I'SOT) grant from the Idaho Operations Office to drill an exploratory geothermal well on I'SOT Inc. property. I'SOT Inc. faced challenges almost immediately.

A two-to-three week drilling schedule turned into three months; finding an expected resource before 1600 feet turned into finding one around 2100 feet; an anticipated flow of 200 gallons per minute (gpm) yielded only 37 gpm. I'SOT Inc. found, however, a resource with a bottom hole temperature of 223°F, making possible a usable resource temperature between 190-200°F instead of the expected 150-160°F. By the middle of 2001, disposal of the geothermal effluent also became an issue after arsenic and mercury were discovered during subsequent water analysis (concentration averages of 102 μg/L and 188 ng/L respectively). By this time it was clear that in order to obtain the main project objective to save money by heating with a geothermal resource, the initial plan on how to do that had to change.

The first change to occur was replacing the warm water wetland with the discharge to the surface waters of the Pit River. The Central Valley Regional Water Quality Control Board (CVRWQCB) concluded that disposal of the geothermal effluent to land would not be the best plan because several monitoring wells would have to be drilled and checked monthly for elevated arsenic levels in the ground water. If subsequent lab analysis found this to occur, discharge would be stopped and another plan developed. A dilution credit for arsenic, it was reasoned, could be obtained with the NPDES discharge permit. However, the regulations in California were changing because of the newly developed California Toxic Rule criteria. The maximum contaminant level (MCL) for arsenic was lowered from 50 μg/L to 10 μg/L for arsenic, a drinking water standard. Even though discharge to the Pit River was still very doable with respect to arsenic, the mercury MCL was 50 ng/L and there could be no dilution credits obtained for this chemical constituent. A way to treat the effluent now had to be found and it was discovered, through laboratory testing, that activated carbon removed 99% of the total mercury concentration which surpassed CVRWQCB and US Fish and Wildlife Service (USFWS) requirements.

The Geo-Heat Center initially made materials estimates for the project based on anticipated flow and temperature of the geothermal resource. These estimates were included in the I'SOT proposal to the Energy Commission. The mercury problem, however, required housing the two large granulated carbon filters in the mechanical building, greatly increasing its size and cost. The project engineer also required a back-up boiler and controls to maximize the lower than anticipated flow. At the same time, the engineer simplified the retrofitting task that used the NSF rated distribution piping for storage instead of existing hot water tanks. These changes caused "budget shifts" that had to be addressed by the Energy Commission and authorized (see Budget Change Justifications, page 26).

Predicted expenses and savings for the facilities connected to the geothermal district heating system are shown in Table 1b. Propane savings were calculated using a conservative 90% savings as estimated by Kevin Rafferty of the OIT Geo-Heat Center. Electrical savings were estimated on a building-by-building basis taking into consideration the amount of space heating and domestic hot water heated by electrical means. Greater savings will be realized after a 50ft x 100ft x 14ft food service warehouse and laundry building is sited next to the geothermal discharge line to take advantage of remaining heat in the expended effluent. Building completion is expected in August 2004.

Table 1b

Historical Energy Expenses		Predicted Savings 2004
Ave 2001-2002 Annual Propane Cost	$ 28,115.18	$ 25,303.66
2002 Electrical Cost @ $.061/kWh	$ 46,169.97	$ 26,636.08
Total Annual Electrical & Propane Cost	$ 74,285.15	
Total Electrical & Propane Savings		**$ 51,939.74**
Minus Expenses		
Lab Analysis (1st year)		$ (15,000.00)
Replacement Carbon Filters		$ (4,000.00)
Prefilters		$ (1,000.00)
Discharge fees		$ (2,100.00)
Total 1st Year Electrical & Propane Savings After Expenses		**$ 29,840.00**
Each Year After Electrical & Propane Savings After Expenses		**$ 41,840.00**

The initial project objective was to save 45% in the first three years of operation and 91% thereafter. The estimates in Table 1 show that 46% will be saved in the first year and 62% every year thereafter. The lower estimates take into account discharge permits, water analysis, and decreased flow rates that were not anticipated in the 1998 Geo-Heat Center feasibility study. However, simple payback for the $298,000 invested by I'SOT Inc. is calculated about 7 years. It is anticipated by I'SOT Inc. and the CVRWQCB that water analysis costs could diminish to less than $1,000 per year after the first year of data has been analyzed.

3. Findings, Recommendations and Conclusions

Findings

Geothermal direct-use projects can pose environmental obstacles if discharge is to the surface waters of the United States. The I'SOT Project did not have the option of drilling an injection well for two reasons:

- $450,000 had already been expended to drill the geothermal exploration well. An injection well, while environmentally a more favorable option, was not financially possible due to estimated similar costs.
- Drilling an injection well was not within the scope of the funding agreement.

In order for the I'SOT Project to discharge to the Pit River, I'SOT Inc. obtained a NPDES discharge permit, a federal permit, with the help of the CVRWQCB. This is the central permit from which all other permits are linked. I'SOT Inc. also completed a California Environmental Quality Act (CEQA) review with a Mitigated Negative Declaration (see Figure 4.). The CEQA document simply said that I'SOT had permission to build the project as long as I'SOT Inc. followed the requirements for discharge spelled out in the NPDES permit. Before an NPDES permit is granted, agencies such as the US Army Corps of Engineers (USACOE), the US Fish and Wildlife Service (USFWS), the California Department of Fish and Game (DFG) and the general public are given a review period. The CEQA review period lasts for at least 30 days; and longer if any of the "stakeholders" have a problem with what the CVRWQCB required in the NPDES permit. If the permit is contested at a public water board meeting, more time would be needed to resolve disputed issues. The I'SOT Inc. NPDES permit was uncontested because of the stringent requirements that are currently being met.

What I'SOT Inc. did not understand was how extensive the NEPA review would be in order to receive federal funding. The entire environmental review process was reopened and scrutinized to see if NREL still wanted to get involved. This meant that the US Fish and Wildlife Service, which had previously not contested I'SOT Inc's. NPDES permit, now had to engage in the process once again and write a Biological Opinion on whether the project threatened endangered species such as the bald eagle and Modoc Sucker. The Service would prefer not to write such an opinion because of setting precedent.

Another issue addressed in the NREL NEPA process was Native American rights to monitor trenching activities. NREL insisted that the Pit River Tribe be given an opportunity to participate. This was not necessary for two reasons:

- The project was on private property and not on public lands.
- There were no studies that showed that any part of the I'SOT Project would disturb an identified site of Native American cultural resources.

However, NREL insisted that all precautions be taken. The plan was to offer Pit River tribal monitors a contract for a $5,000 to monitor all trenching activities. The Tribe was interested in the beginning, but a local archeologist undertook monitoring so that project construction could begin. A series of one-on-one meetings resulted in the Pit River Tribe not actively contesting the I'SOT Project.

The I'SOT Project received a Finding of No Significant Impact (FONSI) after the NEPA review was complete. The use of granulated activated carbon to filter geothermal water for discharge to surface waters of the United States, may serve as an important precedent.

Recommendations

In future projects, experience has taught I'SOT Inc. it would be advantageous to go through the CEQA and NEPA environmental process simultaneously if funding opportunities fall within corresponding timeframes. This should ease the approval processes; however, taking advantage of funding opportunities sometimes cannot be seen ahead of time.

During long environmental permitting processes, however, precious time can be lost and project construction time put at risk. It is our recommendation that funding agreements include a mechanism to allow for lengthy environmental reviews.

Conclusions

Constructing the project was the easiest part of the entire process, although the environmental process and weather took up much of the time when workers were not scheduled on other projects. No Native American cultural resources were encountered. Startup of the geothermal system was relatively uneventful.

Customer satisfaction with the geothermal system is high. An informal survey was taken to find out how the end-users were responding to the geothermal system. Most users concur that their homes are warmer now because they have no fear of turning the thermostat higher. The blower also runs for longer times in several buildings because supply air temperatures are not as warm as they would be if heated by propane. However, more even heat results throughout the buildings instead of heating up quickly and cooling down quickly. Most users easily adapted to the sounds from longer blower operation.

Troubleshooting is relatively easier due to the controls that monitor system performance. Adjustments can easily be made to manipulate the system to conform to user demands.

Since December 5, 2003, geothermal fluid production temperature has increased with use. During the first week of pumping, the resource temperature was between 150-160°F; the second week 160-170°F; the fourth week 170-180°F; during the sixth week 180-190°F. Typically, the resource temperature is a function of flow. Flow is determined by customer demand which is a function of outside air temperature. When the outside temperature is about 10°F, the resource temperature climbs to approximately 193 °F at about 32 gpm; when daytime temperatures are in the 50 °F range, the resource temperature decreases to 178-180 °F at about 5 to 7gpm. With respect to the well casing, what we have is an uninsulated column. The ground surrounding the well bore dissipates heat at a certain rate. The faster the geothermal water rises from the aquifer between 2048-2105 ft., the less time it has to cool from the bottom hole temperature of 223°F.

Today, the resource temperature rarely goes below 180°F and has reached 194°F. What is also encouraging is that the water level in the well bore at these higher temperatures is less than 40 feet below ground surface when pumping about 15 gpm. When the production pump was shut down for 5 hours because of a local power outage, the well flowed artesian at about 5 gpm for the entire outage.

There is no indication, at this time, of well depletion with respect to drawdown. A long term (20 years) prediction of well drawdown, at a constant discharge of 37 gpm, was 257 feet according to the Plumas Geo-Hydrology study, page 16. Currently, average geothermal production during winter conditions has been approximately 14-15 gpm. System requirements for summer domestic hot water use are approximately 5-7 gpm.

A reddish-brown clay is coming back up out of the formation. After a month of geothermal fluid production, the 0.35 micron prefilter to the activated carbon filters was impacted with this clay and had to be cleaned and reinstalled into the prefilter housing. We have instituted a weekly maintenance program to clean the prefilters.

4. Future Intent of Grant Recipient to Maintain and Further Develop the Project

With the I'SOT Project now in place, I'SOT Inc. plans to place new buildings within the district heating system area while either improving the energy efficiency of existing buildings or replacing them. These changes will enable the community to expand the benefits of the geothermal system to more users. The first building to be erected will be the new food service warehouse and laundry facility.

A short feasibility study by Kevin Rafferty, formerly of the Geo-Heat Center, calculated that there would be enough energy from the project's discharged 110-120°F effluent to support a 30' x 80' greenhouse. Utilizing this spent effluent will also help meet NPDES temperature requirements to the Pit River.

Another plan is to enhance production of the I'SOT Inc. geothermal well by acid stimulation. Drilling mud is suspected of "plugging up" the fractured bedrock aquifer, resulting in significant friction losses and increased well drawdown. If acidifying the geothermal well is successful, futures plans could include using the existing well as an injection well and drill a deeper, more productive well. A feasibility study may be completed after the drilling of the second well to evaluate possibilities at that time. Operating commercial greenhouses and aquaculture are potential options.

5. Benefits to the State of California

The I'SOT Project will provide over 61% of all (electric and propane) energy needs from a renewable geothermal resource by heating approximately 55,000 ft^2 of residential and commercial buildings. According to conservative Geo-Heat Center estimates (Rafferty, October 2000), the geothermal load for an average year would approach $5x10^9$ Btu.

If the future plans to expand the geothermal system are realized, the Town of Canby could be a model for other small towns that have geothermal resources. These types of direct-use projects, while not having the "sex appeal" of power generation projects, are much easier to develop for two reasons. First, there are extensive low-temperature (> 250°F) geothermal resources in California. Secondly, direct-use technology is well known, does not require technical innovation and is relatively easy to understand. The I'SOT Project is one more project that California can add to its renewable energy portfolio.

6. Final Payment Request

Final payment and retention payment have been approved and paid by the Energy Commission.

7. Consolidated List of Contractors and Subcontractors Funded in part by the Grant Recipient

The Energy Commission grant funds were used only to fund the purchase of project materials and were administered by:

- Modoc Contracting Company
  P.O.Box 7731
  Klamath Falls, OR 97602

Figure 1 – Where's Canby

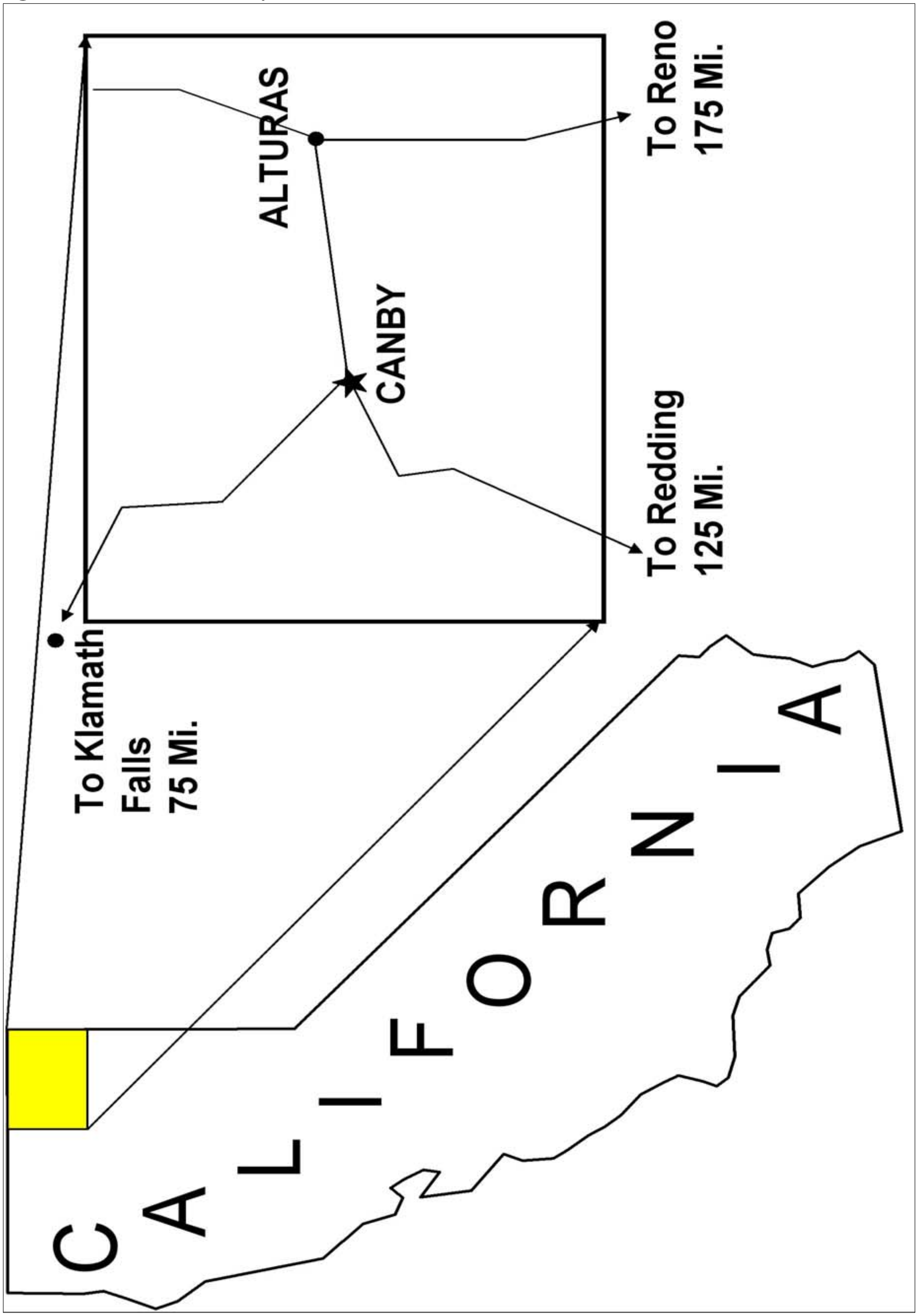


Figure 2 – System Illustration

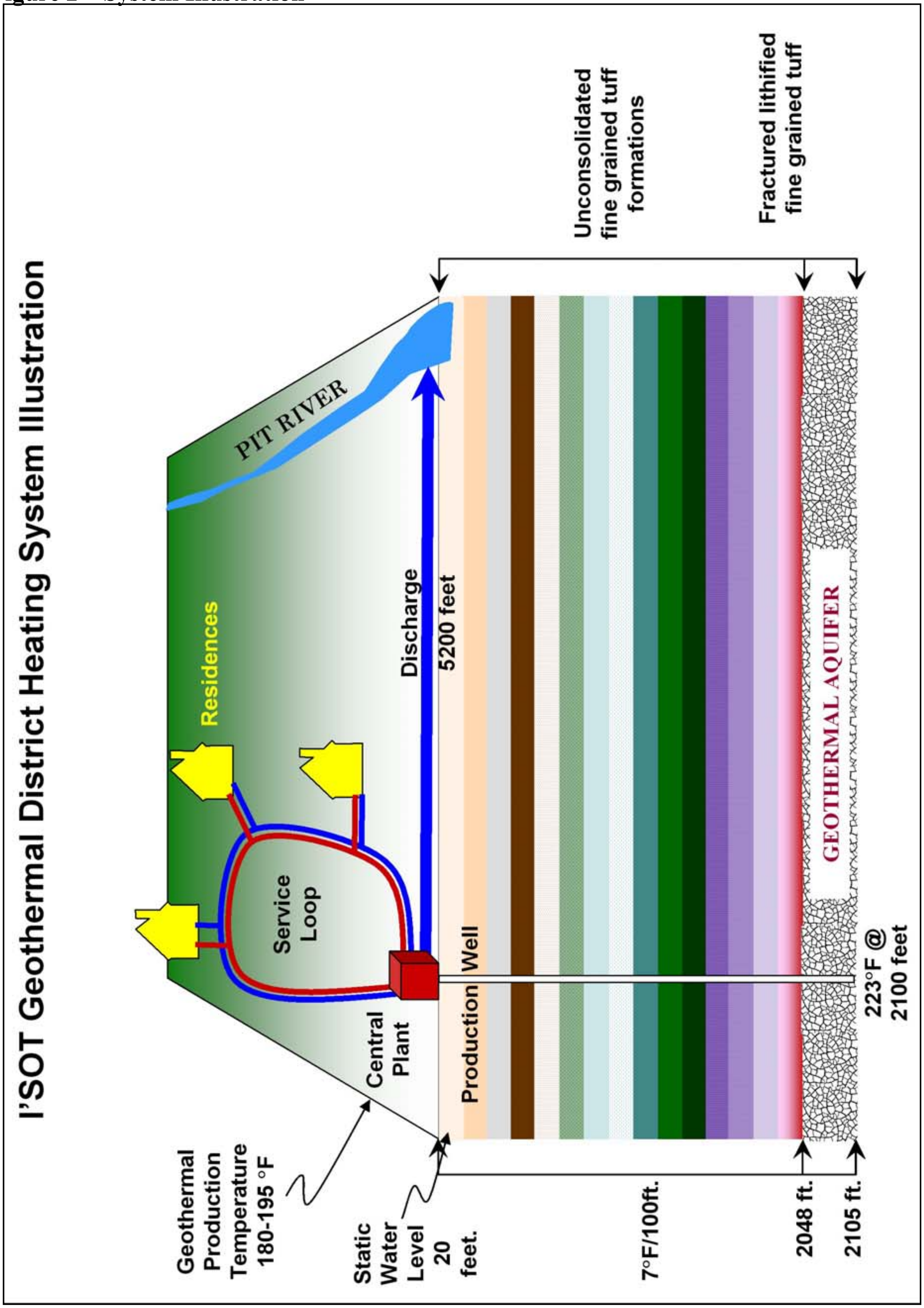


Figure 3 – Overall Project Aerial

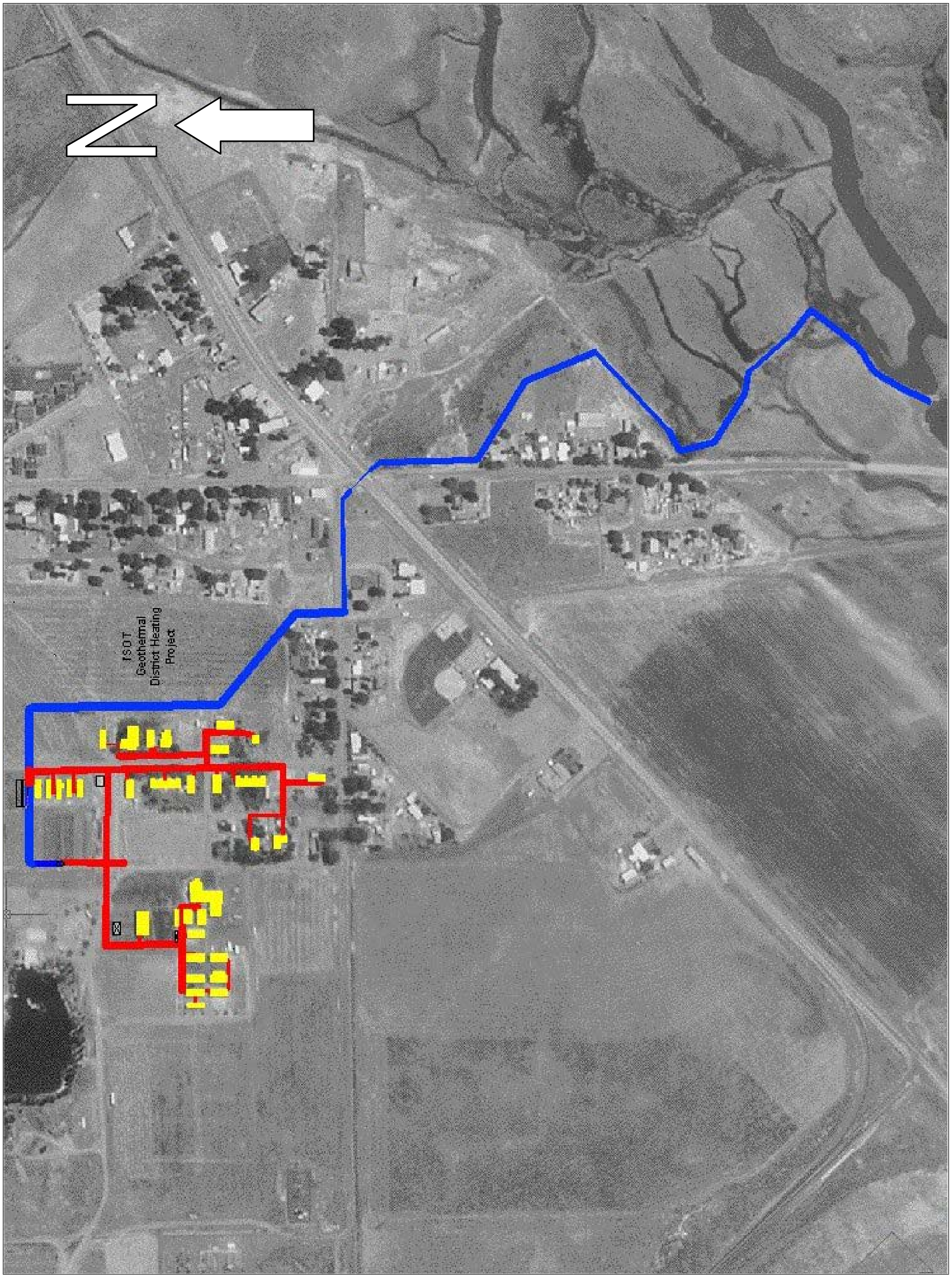


Figure 4 – CEQA / NEPA Flowcharts

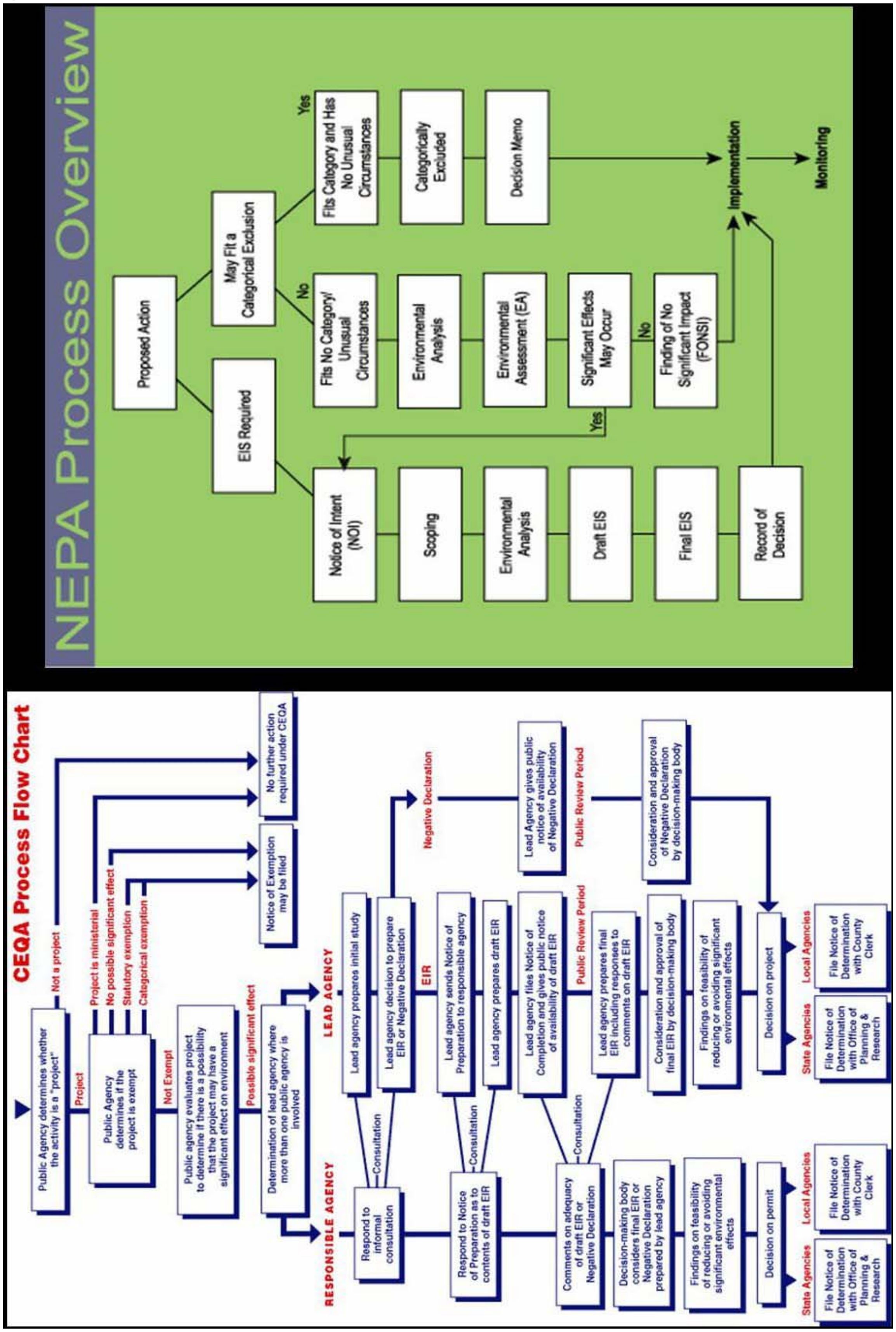


Figure 5 – Well Profile

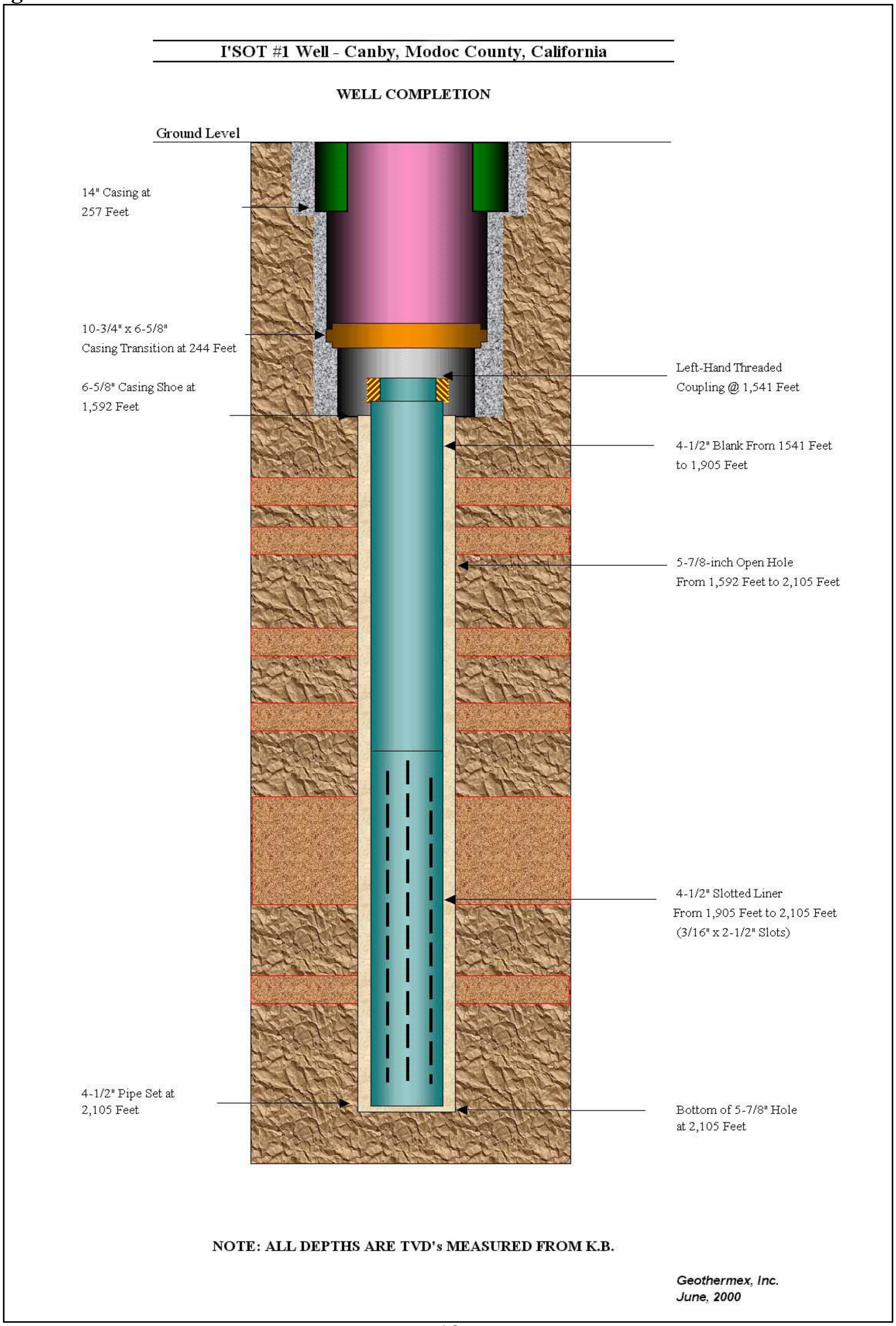
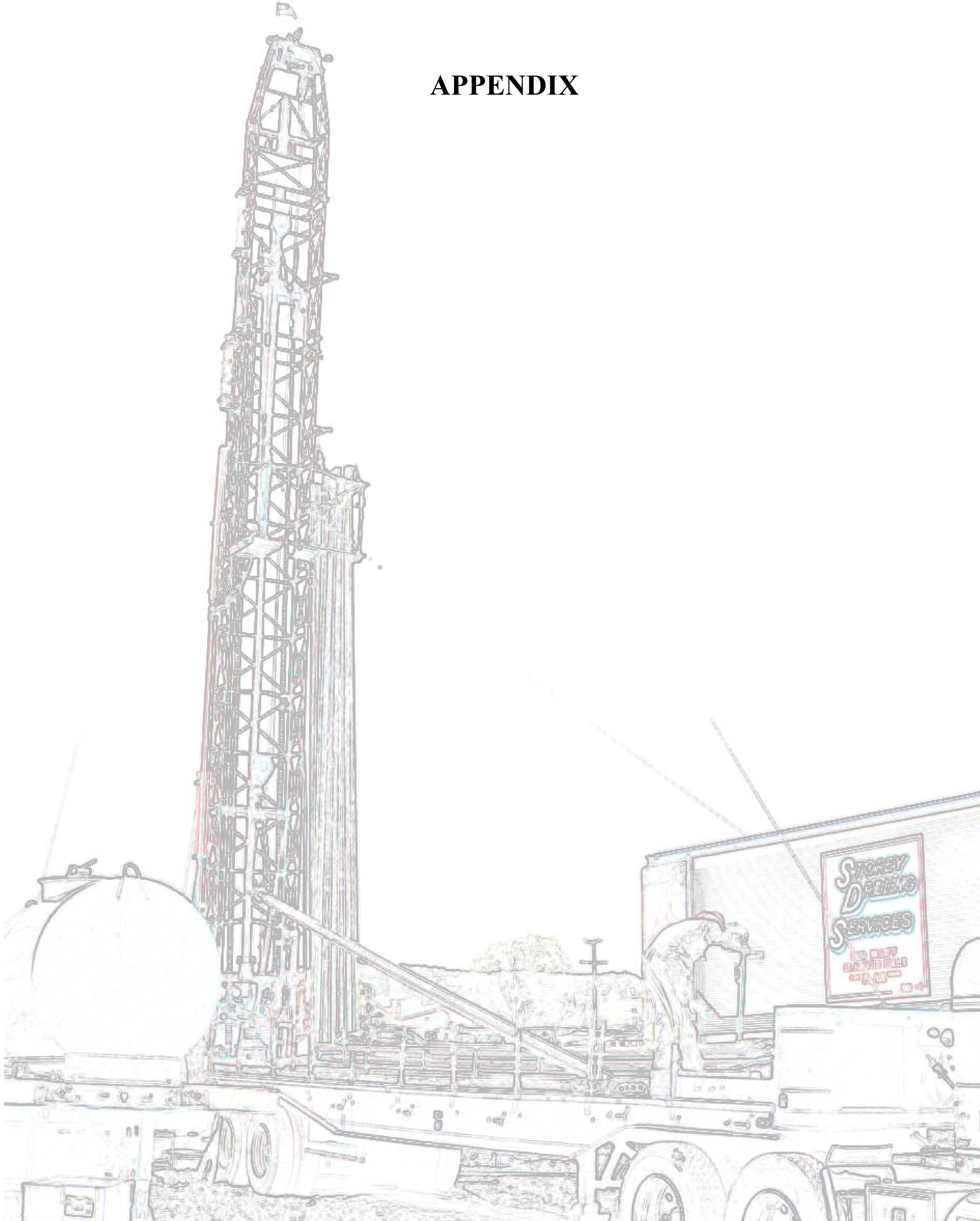


Figure 6 – Carbon Filters

APPENDIX



PLUMAS GEO-HYDROLOGY *P.O. Box 1922, Portola, CA 96122*
LAND AND WATER RESOURCES *phone (530) 836-2208, fax (530) 836-0959*

Well Testing at the ISO-1 Geothermal Well, Canby, Modoc County, CA

Prepared by Burkhard Bohm, Ph.D.
CA Certif. Hydrogeologist No. 337

Final Report, October 18, 2000

Introduction

Geothermal well ISO-1 was drilled in the summer of 2000 in the town of Canby, in Modoc County, California (PGH, 2000). The well was drilled to a depth of 2100 ft, producing from fractured cemented fine-grained tuffs of the Alturas Formation, in the interval below 1900 ft, though most production is probably from a fracture zone around 2050 ft depth. The well was completed with ten inch casing from surface to 255 ft, and with six inch casing to 1600 ft (all cemented). The six-inch borehole from 1600 to 2100 ft contains a four-inch liner with a 200 ft perforated section from 1900 to 2100 ft. The highest temperature of 208° Fahrenheit (F) measured in the borehole was at 2050 ft. It is likely, however, that the actual production zone produces water in excess of that temperature.

The following report is a summary of well testing results for ISO-1.

Well testing format

In order to determine if geothermal well ISO-1 is adequate to provide the discharge needed for the projected use, and to determine the pump size needed and pump depth, standard well testing methodology was applied. For that purpose a submersible motor pump was set with its intake at a depth of 255 ft, within the ten-inch pump chamber. Pump installation was conducted by Modoc Pump of Cedarville, Modoc County. The motor was modified to be able to withstand the anticipated discharge temperatures of about 180°F. Water was discharged into a ditch by means of a two-inch pipe, and then pumped into an area west of I'SOT's sewage lagoon.

The test consisted of an 8-day constant discharge test, preceded by a short step drawdown test. The step drawdown test results were used to decide at what rate the well was to be pumped during the constant discharge test. The results from the constant discharge test were used to estimate the well's long-term productivity and the associated projected long term drawdowns.

The flow was regulated at the wellhead by means of a gate valve. Well water levels were monitored with a standard electric well water level probe. Discharge was monitored by measuring the time it took to fill a 17-gallon oil barrel. The discharge temperature was measured with a digital thermometer.

Step drawdown test

The step drawdown test was conducted by the author, on September 6, 2000. The step drawdown test consisted of four one-hour steps. The discharge for each step and the drawdown-to-discharge ratio at the end of each one-hour step are given in Table 1.

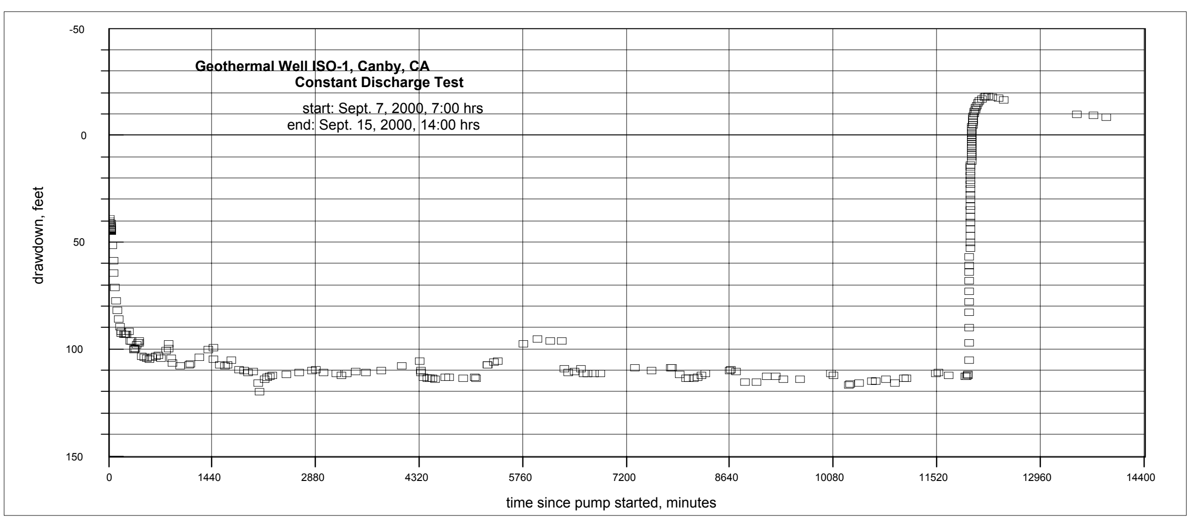
Table 1: Geothermal well ISO-1, step drawdown test results:

	Discharge Q, gpm	Drawdown, s, ft	s/Q, ft/gpm
Step 1:	10.91	19.1	1.59
Step 2:	21.82	62.9	2.88
Step 3:	32.9	127.32	3.87
Step 4:	40.8	212.17	5.49

The data were analyzed with standard methodology as described in Driscoll (1986, page 556).

Given the limited drawdown available due to the pump being set within the well's ten-inch pump chamber, the step drawdown test data analysis suggested that a constant discharge test at a rate of about 25 gallons per minute was reasonable. The long-term discharge rate had to be large enough to adequately stress the well, while at the same time the drawdown after about seven days should still be above the pump intake. A period of at least five days is considered standard and necessary to determine well yields in a well producing from fractured bedrock (as in the case of ISO-1).

Figure 1: Well test data from geothermal well ISO-1.



Constant discharge test

The well was pumped at a constant discharge rate of about 24.5 gpm for a period of 8.3 days (11952 minutes), beginning at 7 am on September 7, and ending at 2:20 p.m. on September 15, 2000. The drawdown data are plotted in Figure 1. The diagram includes the recovery data at the end of the test, after the pump was shut down. The static water level at the beginning of the test was 21.2 ft below top of casing (TOC). After pumping for 8.3 days at an average rate of 24.5 gpm the water level had declined to 133 ft below TOC (112.40 ft of drawdown).

Evidently friction losses were significant, resulting in a huge initial drawdown of almost 110 ft during the first day. Throughout the following seven days the water level declined by not more than ten feet, i.e. by the end of the test the drawdown did not exceed 120 ft.

After the pump was turned off at the end of the test the well recovered by 80% within 21 minutes, and had reached the static water level of 20 ft below TOC within 36 (!!) minutes. This rapid recovery rate is typical for wells completed in fractured bedrock aquifers, suggesting that a great portion of the drawdown during pumping is due to friction losses (turbulent flow) in the fractured aquifer formation.

After 5.4 hours the water level had risen to 3 ft below TOC. The reason why the well recovered to a level above the initial static water level was that by the end of the test the entire water column in the well had heated up, thereby resulting in a static water level greater than that observed when the well was cold. After that the water level declined due to cooling of the water column in the well bore and eventually stabilized at the initial static water level.

The drawdown data were also plotted in a semi-logarithmic plot in Figure 2, commonly used in the so-called Cooper-Jacob well test data analysis method. Although the data show significant scatter due to difficulties in keeping the flow rate constant, and due to diurnal fluctuations (see discussion below), evidently the data did not reach the so-called straight-line segment until 1000 minutes into the test. The long-term drawdown trend after that was extrapolated both from the maxima and the minimum values on the plot, and a transmissivity of 809 gallons per day per ft was calculated with the standard Cooper-Jacob formula. This value is about the same calculated for the similar formations tested in the Alturas wells, AL-1 and AL-2 (GJ&A, 1988; PGH, 1992).

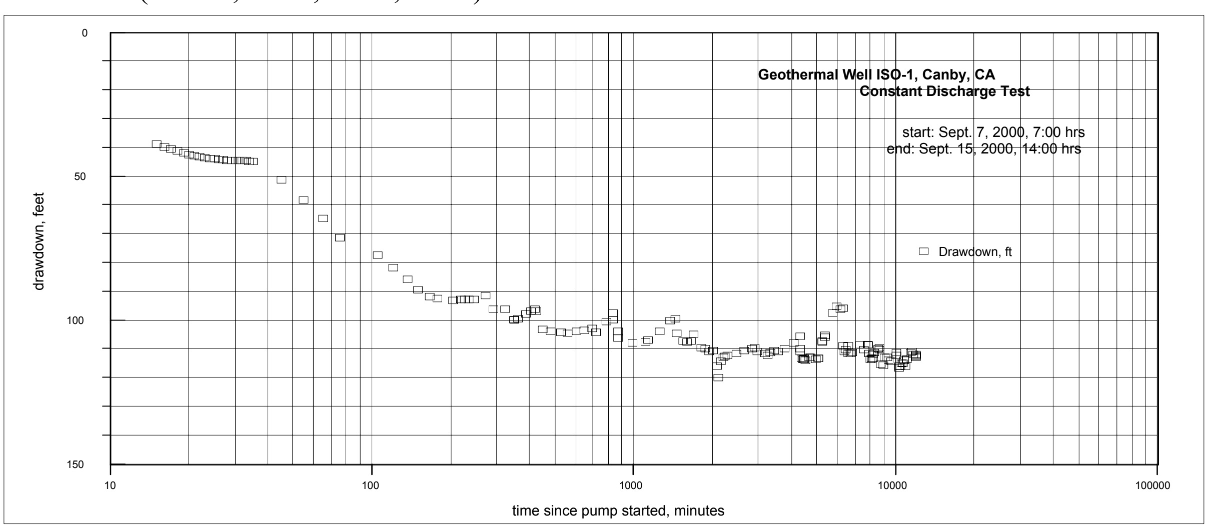


Figure 2: Well test data, semi-log plot

An important consideration is the effect of increasing temperature on pumping water levels. The discharge temperature increased from an initial 110° F at the beginning of the test to about 175°F after 1000 minutes (less than one day). After that the temperature increased by only 10°F, to a maximum of 187°F. In other words, by the end of the first day the well bore temperature practically had heated up almost completely. For all practical purposes the effects of a 10°F increase on the pumping level trend after 1000 minutes was insignificant, (in particular given the scatter of the data).

Productivity analysis

The results of the step drawdown test cannot be used for productivity analysis, since the well did not attain radial flow ("Theis flow") conditions within the four-hour step test. Therefore long term productivity had to be calculated from the slope of the straight-line segment Figure 2, assuming no boundary conditions will affect the well after pumping periods greater than 8 days.

Using the calculated transmissivity of 809 gpd/ft, one can estimate the amount of drawdown at a given discharge rate, using a rearranged form of the Cooper-Jacob equation. After subtracting the initial drawdown during the transition phase to "Theis flow" (before 1000 minutes) by using the well loss equation Driscoll (1986, p. 556), the constants of which are estimated from the step-drawdown test data, the total amount of drawdown after 20 years of continuous flow can be estimated. This is standard methodology applied in the industry.

The calculations indicate that at a long term constant discharge rate of 37 gpm the well water level would be 252 ft below surface, i.e. still within the ten inch pump chamber. Should higher pumping rates be desirable for intermittent peak demand periods a pump could be set to greater depth. For example, at a long term pumping rate of 45 gpm, the water level would decline to 358 ft. below top of casing.

It is important, however, to consider that these estimates are conservative. There are three factors that make this productivity analysis somewhat conservative:

1. During the step drawdown test the well had not yet attained its long-term discharge temperature greater than 180°F, and the results are therefore conservative.
2. The well will not be pumped year round, i.e. it will only be pumped during the six-month heating season from October to April, allowing partial recovery every year (except for direct use of tail water for the Laundromat, which is less than 10 gpm).
3. Eventually the aquifer will attain steady state, although with these data it cannot be predicted when this will occur. It is for sure, however, that in a fracture steady state is attained sooner than in a homogeneous aquifer. Steady state means that pumping water levels will eventually stabilize at a level higher than what has been predicted for 20 years.

In other words, the productivity numbers calculated here were based on data obtained during a four-hour step drawdown test during which the maximum temperature was only 159°F. The constant discharge test data at 24.5 gpm attained a wellhead temperature greater than

180°F. It is to be expected that at 40 gpm, for example, discharge temperature will exceed this temperature, and the well water level will be at a level higher than that predicted from the productivity analysis.

Also, since the well will on the average be pumped only seven out 12 months per year, the long term average pumping rate may be much less, and consequently the long term drawdown will be less. This will provide more flexibility during peak demand periods. For example if the average heating demand during the heating season is about 30 gpm, then the actual annual average demand is less than 20 gpm. In other words, although the well water levels will fluctuate significantly depending on the demand, the long-term well water level will be on the average at about 120 ft below TOC. This should still allow ample space to accommodate peak flow demands.

On the other hand, if during extended periods of extremely cold weather the demand exceeds the supply then the user may have to rely partially on the conventional back-up heating system. The likelihood that this would happen would have to be determined from available climatological data ("bin analysis").

Water quality

A water sample was collected on September 10, 2000 at the ISO-1 wellhead. For comparison the major ion chemistry results are given in Table 2 below, together with data from Kelley Hot Springs (located about 2 miles east of ISO-1) and from seven shallow domestic wells (depth less than 300 ft) in the Canby area.

Total dissolved mineral content (TDS) in ISO-1 is only 752 mg/l, which is a very good water quality for geothermal water, and is only about one half of what was measured in the Alturas geothermal wells.

In situ temperatures at depth were estimated using the Na-K-Ca and silica geothermometers (Fournier, 1977; Fournier and Truesdell, 1974). The results suggest that the aquifer temperature at depth is somewhere between 198 and 242 degrees Fahrenheit, depending on what mineral phases are assumed to be present. The same temperature range was observed in the deep boreholes at Kelley Hot Springs.

Evidently water composition in ISO-1 and Kelley Hot Springs are practically the same, suggesting that both waters are derived from the same geothermal system.

Table 2: Major ion chemistry of wells, Canby Area, Modoc County, California:

	Ca	Mg	Na	K	SO4	Cl	HCO3	NO3	SiO2	F	TDS
Kelley HS	20	<0.01	250	6.5	300	160	47			2.1	783
ISO-1	14	<0.01	240	3.7	280	170	44	-0.3	110	1.9	752
Average shallow wells:	15	8	69		51	24	196	0.5		0.3	356

Summary and conclusions

Well ISO-1 was tested by means of a constant discharge test for a period of 8.3 days, beginning on September 7, 2000. The constant discharge test was preceded by a short step-drawdown test. The transmissivity calculated from the data was 809 gpd/ft. This value is practically the same as in the Alturas geothermal wells, which are also producing from fractured cemented fine-grained tuffs of the Alturas Formation.

The well water level declined by about 110 ft in the first 1000 minutes, but declined by only ten feet during the remaining seven days of the test, with a total drawdown of 120 ft. At the end of the test (once the pump was turned off), the well recovered to static water level 21 ft below TOC, within 36 minutes.

Friction losses in the well are significant and are probably due to non-laminar flow in the major fracture zone at 2050 ft depth. Based on the analysis of these data the well can be pumped on a long term basis at an average pumping rate of 37 gpm, without drawing the water level below the bottom of the ten inch pump chamber. Should higher pumping rates be desirable a pump could be set at greater depth inside the six-inch casing.

Expecting wide variations of pumping rate in response to seasonal weather patterns (i.e. at times pumping maybe much less than 37 gpm), this should allow for occasional higher pumping rates in response to peak demands.

As is typical in the Modoc Plateau, water quality is reasonably good for geothermal water, being almost identical to that from Kelley Hot Springs, located about 2 miles east of ISO-1.

Bibliography

Driscoll, F.G., 1986, Groundwater and Wells. Johnson Filtration Systems, St. Paul, Minnesota.

Fournier, R.O., 1977, Geothermics Vol. 5, p. 41-50.

Fournier, R.O. and Truesdell, A.H., 1973, Geochimica Cosmochimica et Acta 37, pp 1255-1275.

GJ&A, 1988, Siting, drilling and testing of exploratory geothermal well AL-1. Technical summary report prepared by Gertsch, Juncal & Assoc., Milford, CA for Modoc Joint Unified School District, and CA Energy Commission.

PGH, 1992, Drilling and preliminary testing of geothermal well AL-2 at the Alturas Elementary School, Alturas, Modoc County, California. Technical summary report prepared by Plumas Geo-Hydrology for Modoc Joint Unified School District, and CA Energy Commission.

PGH, 2000, Drilling Geothermal Well ISO-1. Technical summary report prepared by Plumas Geo-Hydrology for I'SOT, Inc., August 2000.

GEO-HEAT CENTER
Oregon Institute of Technology e Klamath Falls, Oregon 97601 o 541/885-1750 - FAX 5411885-1754

John W. Lund, Director
Kevin Rafferty
Tonya "Toni" Boyd
Donna Gibson

October 18, 2000

Dale Merrick
3625 Homedale
Klamath Falls, OR 97603

Dear Dale:

As you requested, I have reevaluated the space-heating load for your system in recognition of the flow calculated to be available from the geothermal well. The draft Plumas GeoHydrology report suggests that a sustained flow rate of 35 gpm would be available from the geothermal well over the long term and that the temperature would be in excess of the 180°F figure observed during testing. Given the 225°F bottom hole temperature, I have used a conservative value of 190°F in my calculations.

The peak space heating requirement for the system, based on the data collected from existing heating equipment, is 1,840,000 Btu per hour. This assumes that all heating equipment will be in operation at the same time. In reality, when a large group of buildings are connected in a single system, the diversity in use, occupancy and orientation of the buildings results in only 65 to 85% of the heating equipment operating at any given time. Conservatively applying an 80% diversity factor for this system results in an actual peak requirement of 1,472,000 Btu/hr. Assuming a distribution loss of approximately 150,000 Btu/hr, this would suggest a total peak requirement of 1,622,000 Btu/hr for the combined load.

Using hot water coils installed in the existing heating systems, it is reasonable to expect that these could be operated at a temperature of 140°F supply and 100°F return, and still be capable of delivering 105°F air to the space. Given these temperatures and a 190°F geothermal temperature delivered to the heat exchanger, the exit geothermal water could be reduced to I10°F easily. With a flow rate of 35 gpm and a temperature drop of 80°F, the geothermal would be capable of delivering 1,400,000 Btu/hr. Although this is only 86% the required peak load, this reduced capacity is still capable of displacing in excess of 95% of the fuel used for space heating.

The enclosed table is a portion of a spreadsheet used to calculate the percentage of total annual fuel use which can be displaced by a geothermal system designed to meet only a portion of the peak load. **Column I** is a series of outdoor temperatures indicative of 5°F increments (called temperature "bins"). For example 47°F represents the interval from 45 to 49°F. **Column 2** indicates the number of hours per year occurring in that temperature interval using long-term Klamath Falls weather data. **Column 3** shows the space-heating load for this system at that outdoor temperature. **Column 4** indicates the capacity the geothermal system can deliver.

Column 5 shows the net capacity. A positive number indicates that the geothermal system has excess capacity, which could be used for other loads such as domestic hot water. A negative number indicates the supplemental fuel would be required from another source. **Column 6** indicates the annual energy requirement occurring in a specific temperature interval and the total annual energy requirement appears at the bottom of the column. **Column 7** indicates the annual energy the geothermal system can deliver for that temperature interval. **Column 8** calculates the amount of backup energy required and the total at the bottom of the column.

As indicated at the top of the sheet, that geothermal system could capture over 99% of the annual space heating requirement of the buildings despite being capable of meeting only 86% of the peak heating load. This is possible due to the fact that the peak heating load occurs during only a very few hours per year. Even when the capacity of the geothermal system is insufficient to meet the load, it continues to operate supplying a portion of the load. As indicated in Column 5, insufficient geothermal capacity is not encountered until an outside temperature of approximately 7°F is reached. This condition occurs, on average, only 64 hours per year.

The spreadsheet assumes a perfect system in terms of design and operations condition that would obviously not occur in practice. Allowing for controls drift, equipment cycling and related "real world" issues would reduce the indicated geothermal fraction to a value in the range of 95% in all likelihood.

In summary, despite the substantially lower production rate from the geothermal well in comparison to that envisioned in the original proposal, it remains possible, provided careful design, to capture virtually all of the anticipated space heating savings.

If you have any questions regarding this information, please don't hesitate to contact me.

Sincerely,

Kevin Rafferty, P.E.
Associate Director

KR/dg

Enclosure

Geothermal Design

1,400,000 Btu/hr Annual Geothermal Fraction **0.998**
1,622,000 Btu/hr Total Load

1	2	3	4	5	6	7	8
Outside Temperature Bins	Hours /Year	Space Heating Load	Geothermal Capacity	Net Capacity	load	Geothermal Load	Backup Energy Required
62	551	143118	140000	1256882	78858018	78858018	0
57	658	262383	140000	1137617	172648014	172648014	0
52	783	381648	140000	1018352	298830384	298830384	0
47	826	500913	140000	899087	413754138	413754138	0
42	931	620178	140000	779822	577385718	577385718	0
37	1044	739443	140000	660557	771978492	771978492	0
32	1132	858708	140000	541292	972057456	972057456	0
27	675	977973	140000	422027	660131775	660131775	0
22	352	1097238	140000	302762	386227776	386227776	0
17	150	1216503	140000	183497	182475450	182475450	0
12	82	1335768	140000	64232	109532976	109532976	0
7	39	1455033	140000	-55033	56746287	54600000	2146287
2	17	1574298	140000	-174298	26763066	23800000	2963066
-3	6	1693563	140000	-293563	10161378	8400000	1761378
-8	2	1812828	140000	-412828	3625656	2800000	825656
	7,248.00	0.00					
	1,512.00				**4,721,176,584**	**4,713,480,197**	**7,696,387**

I'SOT Inc.

P.O. Box 125
Canby, CA 96015
(530) 233-5151

September 28, 2002

Gail Wiggett
CEC Geothermal Project Manager
1516 9th Street, MS 43
Sacramento, CA 95814-5504

Subject: Budget Shift Justifications

Dear Ms. Wiggett,

The original I'SOT Geothermal District Heating Demonstration Project goal to save energy costs is still alive and well. With the volatility of the energy market because of the unstable situation in the Middle-East, our project makes more sense today than it did when the proposal was first conceived

There has been a significant budget shift, however, during the process of meeting project challenges. The following letter will attempt to explain how those changes occurred.

Original Design Assumptions

When Kevin Rafferty of the OIT Geo-Heat Center began estimates for our geothermal project in 1998, there were basic assumptions that were made in the preliminary design for the district heating system.

1) It was expected to find a geothermal resource before 1600 feet below the surface with a temperature of approximately 150°-160° F at 200 gpm.
2) The water quality was expected to be similar to Kelly Hot Springs; therefore, disposal was not thought to be an issue.
3) Space heating was the main focus of the original plan with domestic hot water being a secondary issue.

What we found was a resource at 2100 feet with a temperature of 180° -190° F at 37 gpm and a water quality that was indeed similar to Kelly Hot Springs except with 150 ng/L Hg. Another change was having an engineer that believed that 99% of space heating **and** domestic hot water needs could be met.

A report submitted to your office said,*" In summary, despite the substantially lower production rate from the geothermal well in comparison to that envisioned in the original proposal, it remains possible, provided careful design, to capture virtually all of the anticipated space heating savings." Kevin Rafferty, Geo-Heat Center, October 18, 2000*

Brian Brown Engineering (BBE) was chosen for the project because of his extensive geothermal work in the Klamath Falls area. BBE has provided the "careful design" required for the project. BBE was hired in September 2001 after the August 2001 funding agreement. This is also a recipe for change since no two engineers see the solution to any project in the same way. Had BBE been hired earlier in the year before a signed funding agreement, some of the following budgetary changes may not have been as pronounced.

Below are the budget changes. The project engineer generated a materials list that was given to Modoc Contracting (MC). MC then supplied the following costs to each task below.

2.2.1 Central Plant (building) – from \$8,000 to \$21,398.45

The estimate in the August funding agreement envisioned a simple 8'x8' building for the well and central heat exchangers.

The budget changes in the Central Plant Building were caused by:

1) The space needed to house filters needed for mercury mitigation. Two USFilter PV2000 carbon adsorption vessels along with a piping manifold required to hook them in series each stand over 9 feet high, 4 feet wide and need a 12'x12' overhead door to service. A door of this size requires an eave height of 14', hence the need for a larger building. It also required the need for an engineered building instead of a small wooden structure built to code.
2) The space needed to house a peaking boiler added to the central plant to dramatically reduce original retrofit costs.

2.2.2 Central Plant (mechanical) – from \$30,000 to \$54,641.96

The estimate in the August funding agreement envisioned the basic mechanical equipment lined out in the 1998 Geo-Heat Center calculations, page 88 of proposal.

The budget changes in the Central Plant were caused by:

1.) The expense of two USFilter PV2000 carbon adsorption vessels.
2.) The expense of a peaking boiler to the central plant to dramatically reduce original retrofit costs.

***2.2.4 Distribution Piping* - from $143,000 to $127,695.58**

The estimate in the August funding agreement was based on a scaled back 1998 estimate by the Geo-Heat Center, page 87 of proposal.

The budget changes in the Distribution Piping were caused by:

1.) Careful design of the heating loads required at Building Groups A&B greatly reduced the cost of distribution piping.

***2.2.5 Retrofits* - from $70,000 to $53,387.92**

The budget changes in the Retrofits were caused by:

1.) Going to a centralized system with a peaking boiler at the Central Plant. This cut costs of the retrofit by replacing every heat exchanger at every hot water tank with a mixing valve, so that incoming 160°F water would be "mixed down" to 120°F for showers and kitchen use.

***3.1 Discharge Pipeline* - from $7,750 to $4,005.10**

The budget changes in the Retrofits were caused by:

1) The project engineer eliminating hot water from going into the discharge line, thereby not needing expensive CPVC piping.
2) Finding a good deal on pipe.

***Controls* - $43,395.99**

Controls were added to the budget:

1.) In order to maximize the geothermal resource. The control system will have the ability to "take over" every furnace in every building. Since we have a variety of HVAC systems, it is important that the entire system work as one system. The control system is "intelligent" enough to know when there is a problem and can give the needed information in order to efficiently troubleshoot.
2.) In order to help limit a hot discharge from the central plant to meet NPDES discharge requirements. Tight control of the system is necessary in order to meet the discharge temperature requirements and to meet the heating demand with a limited resource.
3.) The control system will also provide extensive monitoring capability to confirm system performance and energy savings.

We ask your careful consideration to these changes as we deem them necessary for the project to function as designed by the project engineer.

Sincerely,

D. Merrick

Dale Merrick
Principal Investigator
I'SOT Inc.